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LEVEL II

A SYSTEM FOR ESTABLISHING OCCUPATIONALLY-RELATED GENDER-FREE PHYSICAL FITNESS STANDARDS

US ARMY RESEARCH INSTITUTE
OF
ENVIRONMENTAL MEDICINE
Natick, Massachusetts

APRIL 1980

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The Army's desire to utilize greater numbers of women in physically demanding, non-traditional occupations has created the need to match individual capacities with occupational demands. Research has been conducted to develop a process by which objectively determined physical demands of MOSs can be converted into gender-free physical fitness standards. These standards could then be used both for MOS assignment qualification as well as assuring maintenance of fitness commensurate with job demands. The process was initiated by compiling individual task lists from which cluster of MOSs were formed of those with similar physical

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demands. The most demanding MOS tasks within each cluster were then measured for their acutal physiological cost, force required and/or energy expended, with these costs then being converted into equivalent physiological capacities. These capacities were expressed in terms of muscle strength and aerobic power (stamina) which can be assessed at the time of entrance into the service as well as during periodic on-the-job evaluations. This research has resulted in the derivation of five sets of standards, encompassing three levels of demand within two categories of fitness (strength and stamina). The process describes a system by which physically demanding occupations can be assigned on a gender-free basis which will be scientifically defensible.

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Technical Report

No. _____

A System for Establishing Occupationally-Related Gender-Free Physical Fitness Standards

by

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Abstract

The Army's desire to utilize greater numbers of women in physically demanding, non-traditional occupations has created the need to match individual capacities with occupational demands. Research has been conducted to develop a process by which objectively determined physical demands of MOSs can be converted into gender-free physical fitness standards. These standards could then be used both for MOS assignment qualification as well as assuring maintenance of fitness commensurate with job demands. The process was initiated by compiling individual task lists from which clusters of MOSs were formed of those with similar physical demands. The most demanding MOS tasks within each cluster were then measured for their actual physiological cost, force required and/or energy expended, with these costs then being converted into equivalent physiological capacities. These capacities were expressed in terms of muscle strength and aerobic power (stamina) which can be assessed at the time of entrance into the service as well as during periodic on-the-job evaluations. This research has resulted in the derivation of five sets of standards, encompassing three levels of demand within two categories of fitness (strength and stamina). This process describes a system by which physically demanding occupations can be assigned on a gender-free basis which will be scientifically defensible.

Key Words: Physical fitness standards, occupational standards, aerobic fitness, muscular strength, job tasks, energy cost

I. Forward

This report describes a system which was developed to derive physical fitness requirements for all Army enlisted Military Occupational Specialties. This was a joint effort of the Exercise Physiology Division of USARIEM and the Physical Training Study Group, Directorate of Training Development, US Army Infantry School and was a portion of the Army's Physical Training Revision Project under the direction of HQ-Army Training and Doctrine Command, Fort Monroe, VA.

At the time of writing of this report, HQ-DA has decided not to implement this system of MOS related requirements for establishing fitness training (on-the-job) standards. It is anticipated, however, that standards derived in this study will be utilized for MOS qualification and assignment at the time of entry into the service. The authors, also feel that the results reported here are a significant contribution to the scientific literature and are of interest to many other government agencies in achieving gender-free fitness standards.

The views, opinions and findings contained in this report are strictly those of the authors and should not be construed as an official Department of the Army position, policy or decision.

II. Introduction

The General Accounting Office recommended to the Armed Services in May 1976 that they --"develop standards for measuring the ability of personnel to satisfy strength, stamina and operational performance requirements for specialties where such attributes are factors in effective performance". This action was in response to the arbitrary closure to women of many military occupational specialties (MOS) presumed to be too physically demanding.

With the need to utilize increasing numbers of women in nontraditional MOSs as well as to respond to affirmative action policies, it became apparent that the Army could qualify and assign new entrants by matching individual qualifications with specific MOS physical requirements, regardless of gender Arbitrarily barring all women from a physically demanding MOS, because it is judged beyond the capacity of the average women, is wasteful of manpower, if not, unjustifiable. Thus, In July 1977, the Army Vice Chief of Staff directed that research begin to establish gender-free occupationally related physical fitness standards which could be used for MOS selection and assignment as well as a component of the Army's physical training standards. This paper presents a system by which this can be accomplished.

III. Background

The system is based on the following series of assumptions.

Assumption No. 1: Standards should be established for two separate components of physical fitness - aerobic fitness and muscle strength fitness.

Physical fitness can be defined in terms of the various capacities of the body to carry out physical activity. These capacities are best described by the source or processes of energy generation for muscular exertion. These energy sources are physiologically quite distinct and therefore no single capacity or fitness measure is adequate to encompass physical fitness in the terms necessary to define the variety of Army MOSs.

Physiologically there are three distinct energy sources and thus three physical fitness components. These are illustrated in Figure 1. Brief muscular activity, such as the lifting of boxes or artillery rounds, derives energy predominantly from phosphate compounds stored in the muscle cells. On the opposite end of the spectrum, energy to sustain long term dynamic movement, such as running or repetitive light lifting, is provided from metabolic pathways which utilize oxygen to convert substrates into useable energy. The third energy source which plays an intermediate role between stored and aerobically derived energy is that derived from anaerobic metabolic pathways. In this latter system, conversion of substrate to energy does not require oxygen. This source is utilized when stored energy is depleted and the demand rate exceeds the velocity and capacity of the aerobic system.

MUSCLE ENERGY SOURCE	STORED	ANAEROBIC METABOLISM	AEROBIC METABOLISM
EXAMPLE OF ACTIVITY	LIFTING	SPRINTING	RUNNING
CAPACITY MEASURED AS	MAXIMAL CONTRACTION FORCE	ENDURANCE TIME AT HIGH INTENSITY	MAXIMAL O_2 UPTAKE
TERMINOLOGY	MUSCULAR STRENGTH	ANAEROBIC POWER / MUSCULAR ENDURANCE	AEROBIC POWER / STAMINA

Figure 1. Components of physical fitness in terms of energy sources

Most physical exertion is in fact a combination of these fitness components. While strength and aerobic fitness are relatively easy to isolate and identify, anaerobic fitness overlaps extensively with the other two and is quite difficult to separate and measure. It is for this reason, as well as simplicity, that in establishing occupationally related standards, it was decided to operationally use only two components of fitness, muscular strength and aerobic fitness.

> Assumption No. 2: Standards should be based on objectively determined physical demands of MOSs.

The capability exists to actually measure the aerobic energy costs and calculate the forces exerted in individual tasks performed in the field. Thus, standards based objectively on actual physiological demands are preferable to subjective determinations of task demands, i.e., impressions, perceptions, estimations or judgements.

> Assumption No. 3: Standards should be established for groups or clusters of MOSs having apparently similar fitness requirements.

There are approximately 350 enlisted Army MOSs. Many have similar, if not identical, physical tasks and therefore physical fitness requirements. For this reason as well as simplicity and ease of administration, the smallest number of different fitness standards would be desirable. Thus, MOSs having apparent similar physical demands would be grouped together so as to reduce to the minimum the number of established standards.

> Assumption No. 4: Standards should be based on the most demanding tasks found within each MOS grouping.

Since a soldier must perform every task within his MOS, it was decided to establish standards based on the most demanding tasks within that MOS grouping. This process was selected instead of using the average demand of all tasks.

> Assumption No. 5: The resolution or sensitivity of the scale of standards should be commensurate with operational needs.

The application or administration of fitness standards in the field must be simplified as much as possible if they are to be accepted at all. This is due to the magnitude and diversity of Army personnel and their locations. A scale of standards with many graduations would defeat the purpose intended. Sufficient resolution however, should be established which separates any differences in aerobic and muscular strength demands which are meaningful in terms of job performance.

IV. Methodology

A summary of the steps developed to derive gender-free, occupationally related physical fitness standards is shown in Figure 2.

Step No. 1. The initial step of this process was to assemble a list of all physically demanding tasks for each MOS. Each Army service school provided a detailed description of the physically demanding tasks of MOSs for which they are the proponent. Provision of insufficient information or unrealistic descriptions were rechecked and verified until the investigators were satisfied that the information was accurate.

Step No. 2. The next step was to visually inspect these physical task lists and group MOSs into clusters with similar fitness demands by using a set of objective criteria. These clustering criteria are shown in Table 1. These criteria, one for muscular strength and one for aerobic power demand, were derived by plotting the full range of individual task values observed in the task list and then establishing three levels which divided the total range into approximately equal parts by taking into account natural concentrations of points. This process is illustrated in Figure 3.

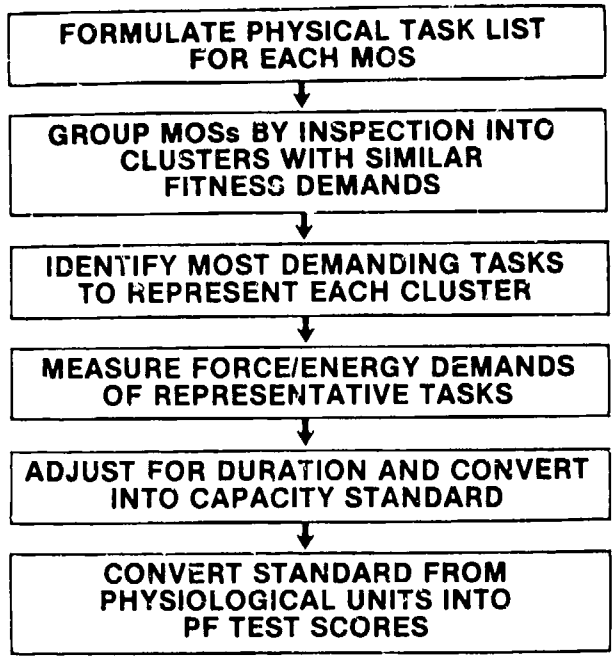

Figure 2. Sequence of steps taken to develop occupationally related fitness standards.

TABLE 1. MOS Clustering Criteria

Intensity Rating	Strength Demands (kg weight lifted to waist height)	Aerobic Demand (energy cost in Kcal/min
Low	<30	<7.5
Medium	30-40	7.5-11.25
High	>40	>11.25

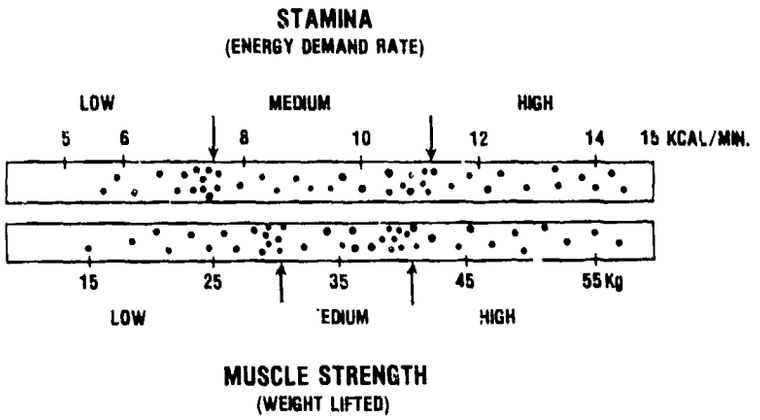

Figure 3. A representation of how objective criteria were chosen for MOS clustering.

Step No. 3. Once the grouping had been completed and clusters of MOSs with like demands were formed, the task lists of each cluster were again examined to select those to be the most demanding. Four to six of the most demanding tasks in each cluster were selected for detailed physiological analysis. These selections were made by evaluating weights lifted, heights to which lifted, distances carried and estimated caloric expenditure of the task. The latter was based on previously published energy costs of both civilian and military tasks (1-3).

Step No. 4. The next step consisted of actually measuring the energy costs and verifying the weights lifted and distances moved for the representative (most demanding) tasks. Soldiers from the Training Center, Ft. Jackson, SC and the 24th Infantry Division, Ft. Stewart, GA were utilized for these measurements.

Caloric costs of tasks were determined by measuring oxygen consumption with the Kofranyi-Michaelis portable respiratory gas meter (3). The subject inspired through a mouthpiece and valve so that the expired air was delivered to the meter carried as a back pack (weight of 3.8 kg). The meter directly measured expired ventilation and produced an aliquot of gas for separate fractional analysis of oxygen and carbon dioxide. These two gas concentrations plus expired minute ventilation were used to calculate the oxygen consumed each minute. This was converted to kilocalories using the conversion ratio of 5 kcal per liter of oxygen consumed.

Step No. 5. The energy cost of the tasks selected in Steps No. 3 and 4 was measured over a period of time (10-20 minutes) sufficient to produce a stable period of oxygen consumption. This period did not necessarily have to equal the actual length of the task as described but only long enough to accurately ascertain the average energy expenditure rate of the task being performed at the prescribed intensity. Most tasks were considered as being performed on a sustained basis (short rest to work period ratios) and therefore the measured rate was utilized as the eight hour average sustained rate.

The next step was the crucial one of converting the eight hour sustained energy cost rate into the necessary aerobic capacity for an individual to perform at that level of intensity. A number of reports (4-6) have suggested that average energy expenditure rates for an 8 hour work day should not exceed 35 to 50% of one's aerobic capacity in order to prevent an inordinate amount of fatigue from which one could not recover overnight. Thus, using a 45% figure, if the highest energy cost of a representative task was found to be 8 kcal per minute, then a person would be required to possess an aerobic capacity of not less than 18 kcal per minute or a maximal oxygen consumption of 3.6 liters per minute. We employed the percentage figure of 45%. At this point, the requirement or standard was established in terms of physiological units (kcal or liters of oxygen) for aerobic demand and physical units (weight and distance) for strength demand.

Step No. 6. The final step was to convert these physiological and physical units of capacity into two separate sets of physical fitness test scores or standards, one to be applied at the time of entrance qualification and the other on-the-job within the MOS (Figure 4). The differences between these two tests are in the mode of testing and the test score standard.

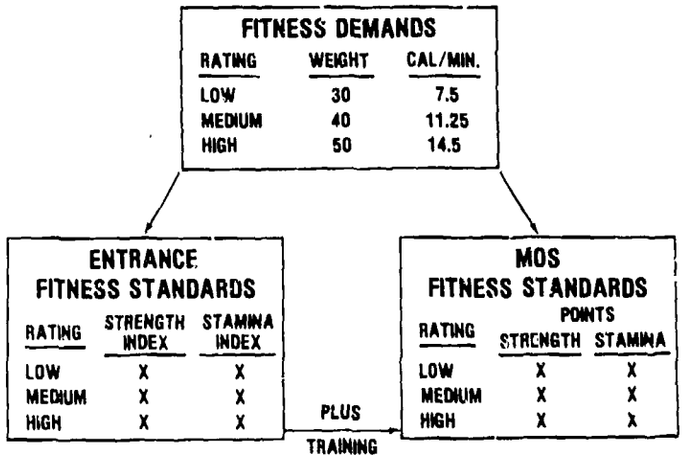

Figure 4. Scheme for converting MOS demands into entrance as well as on-the-job standards.

The entrance test would be administered at the Armed Forces Examining and Entrance Stations (AFEES) where laboratory type equipment and procedures can be utilized to yield relatively precise measures of aerobic and strength capacity. In the "field", on-the-job, we are limited to the use of performance tests such as running, push-ups, etc. The other difference is that the entrance standard would be less than the "on-the-job" standard by an amount equal to the average expected gain during basic and advanced individual training. The test events presently being considered are listed in Table 2.

Capacities from Step No. 5 would then be converted into equivalent scores on these two sets of tests through the means of regression (correlational) analysis. Figure 5 represents, for illustrative purposes only, the relationship that can be developed between aerobic capacity and the two mile run time. The relationship shown is based on data from Ribisl and Kachadorian (7). Similarly, Figure 6 illustrates the relationship that can be developed between lifting capacity and an isometric strength measurement. These data are unpublished findings from this laboratory.

Table 2

Physical Fitness Test Measures for
Entrance and On-the-Job

Component	Entrance (AFEES)	On-the-Job
Aerobic	Heart rate from step test plus % body fat.	2 mile run
Muscle strength	Isometric upright pull at 38 cm.	Push-ups Sit-ups Squat-thrusts

V. Results

A. Physical Task List

Based on information provided by the service schools, the physical tasks of 349 enlisted MOSs were compiled. An example of a task write-up is given below:

MOS 12E, task-1: Backpack an ADM.

Condition: given an XM120E1 in the H-911 bay secured to the backpack, cross-country route, under daylight conditions.

Standard:

i. lift a 30 kg XM120E1
ii. backpack ADM 1 km
iii. perform task in 20 minutes
iv. perform task 2 times per day

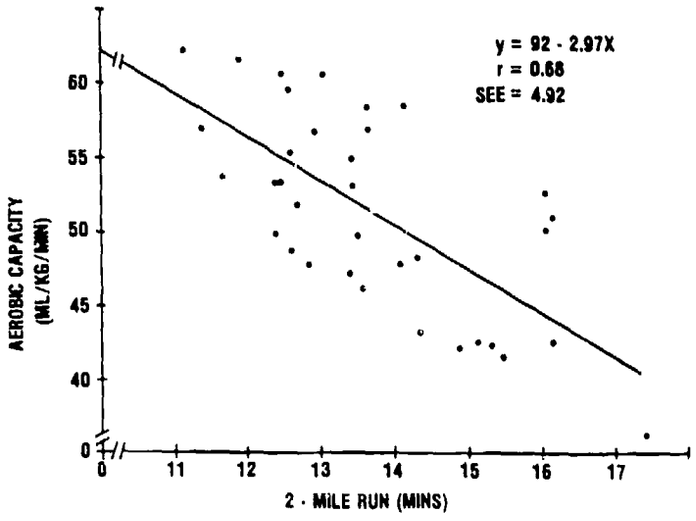

Figure 5. Example of relationship between aerobic capacity and 2 mile run time (Ref. 7).

B. Clustering of MOSs by Fitness Demand

Using the procedure of assessing task demand by level of intensity (Table 1) in two categories of fitness, five clusters resulted out of a possible nine combinations (Table 3). The combinations not appearing simply did not occur or, did so rarely that it was prudent to include them in the next closest cluster. Table 4 presents the five clusters in terms of distribution of MOSs and personnel. Table 5 lists the individual MOSs in each cluster. This listing may not be current since MOS tasks periodically are modified which may move them to a different cluster.

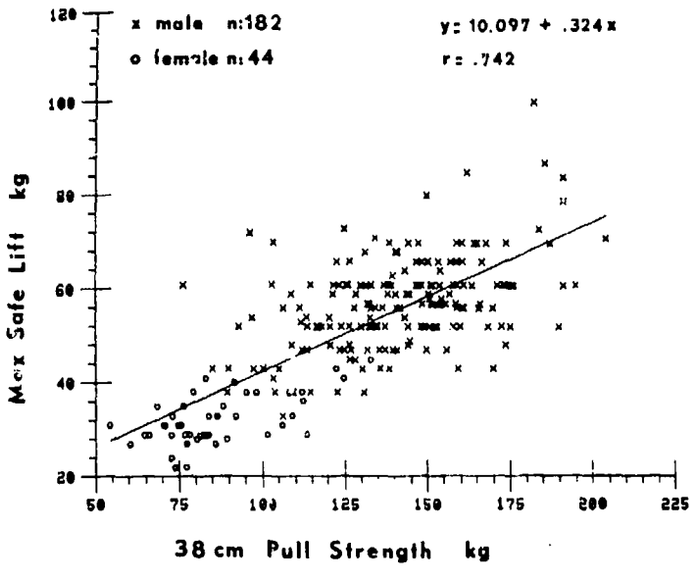

Figure 6. Example of relationship between maximum lift capacity and isometric upright pull strength.

Table 3

MOS Clusters

Level of Demand		Cluster
Strength	Aerobic	Designation
High	High	Alpha
High	Medium	Bravo
High	Low	Chairlie
Medium	Low	Delta
Low	Low	Echo

Table 4

MOS Cluster Distribution

Cluster	Number of MOSs	% of Total MOS	% of total Personnel
Alpha	10	3	19
Bravo	39	11	13
Charlie	63	18	21
Delta	53	15	21
Echo	184	53	26
	349		

C. Representative Most-Demanding Tasks

Table 6 presents an example of representative tasks selected for each cluster to be used for cost measurements. Special note should be taken of the Echo cluster tasks. Echo cluster included all MOSs which have no, or only minimal, physically demanding tasks within their job description. Thus, there were no physical tasks upon which to base a fitness standard. It was therefore decided by HQ-Training and Doctrine Command that a group of tasks would be formulated which could be used to derive the fitness standard. These tasks, referred to as "common soldiering tasks", were selected by a committee at the US Army Infantry School to represent those tasks which all soldiers must be able to perform, at a minimum, in a wartime defensive situation. These were also tasks which were to be accomplished by the end of Basic Initial Entry Training.

D. Measurement of Energy Cost

Table 7 presents, for illustrative purposes, the energy cost for ten soldiers of one representative task. It can be noted that the oxygen demand or caloric cost of a task is independent of body size when a large load is carried. This is due to the fact that differences in body weight became inconsequential relative to the total weight being moved.

E. Convert Cost into Capacity and Test Standards

Demand for muscular strength was expressed in terms of weight lifted to a height of 132 cm. Thus, the greatest lifting demands identified in the cluster representative tasks were converted into this unit (adjusted for height lifted) and expressed as the required absolute strength capacity. For aerobic capacity, 8 hour energy demands were set not to exceed 45% of capacity and aerobic capacities thereby calculated.

Table 5

List of Individual MOSs Assigned to Each of Five Clusters

ALPHA	BRAVO		CHARLIE			DELTA		
ENGR	AR	MED	ADA	FA	ORD	ADMIN	INTEL	QM
12B	19D	91H	16D	13E	34G	71L	17K	43M
12C	19E	91J	16E	15D	44B		26E	57E
51B	19F	91L	16F	15E	45B		33S	76D
51C	19G	91N	24C	15J	45K	ADA	98C	76V
51H	19H	91P	24E	17B	63C	24N	98G	76W
	19J	91Q	24G	17C	63F		98J	76X
		91R	24M	21G	63G		05D	
		91S	24P	93E	63H		05G	SIG
FA	FA	91T		93F		CHAP	05H	26D
13F	13B	91U	AR		QM	71M	05K	26L
		91V	45N	MP	57F			26Q
INF	MED	91W	45P	95B	76Y	CHEM	M/M	26R
11B	30G	91Y	45R	95C	92C	54C	27B	26T
11C	35S	92B		95D		54E	27E	31M
11H	35T	94F	ENGR		SIG		27F	31V
	35U		35E	MSL/MUN	36C	ENGR	27G	34B
MED	42C	MSL/MUN	51M	21L	41E	12E	27H	34J
91B	42D	55B	51N	22N	84F	51R	46N	36D
	42E	55X	52D	24H		52E		05B
	71G		53B	24J	TRAN	62G	ORD	05C
	76J	QM	62B	24K	76G	00B	41C	
	91C	43E	62E	24L	67N		45L	TRAN
	91D		62F	35F	67U	FA	63B	64C
	91E		62H	55D	67X	26B	63J	63B
	91F		62J	55G	67Y			63F
	91G				68D			68J

Echo

ADMIN	ADA	CHEM	FA	MED	MUSIC	SIG	SIG	TRAN	Proponent Unknown
71C	16B	92D*	13W	01H	02J	26V	35B	57H	00D*
71D	16C		13Y		02K	26Y	35K	61B	00Z*
71E	16H	DEF INFO	13Z	MSL/MUN	02L	31E	35L	61C	09B*
73C	16J	71Q	15B*	22K*	02M	31J	35M	61F	09D*
73D	16P	71R	15F	22L	02N	31N	35P	61Z*	09S*
73Z*	16R		82C	23N	02P	31P	35R	64Z*	09W*
74B	16Z*	ENGR		23Q*	02Q	31T	36E	65B*	
74D	24B*	12Z	INTEL	23S*	02R	31Z	36H	65D*	
74F	24D*	41B	17L*	23T*	02S	32D	36K	65E*	
74Z*	24F*	41K	17M	23U	02T	32F	36L	65F*	
75B	24Q	51G	26C	23V*	02Z	32G	72E	65G*	
75C	24U	51P*	26K*	23W		32H	72G	65H*	
75D	25J*	51T*	26M*	24V	ORD	32Z	72H*	65J*	
75E	25K*	51Z*	26N*	27Z	44E	34E	81E	65K*	
75Z*	25K*	52C	41G*	35H	45Z*	34F	84B	65Z*	
79D	25L*	62N*	96B	55Z	54D	34H	84C	67W*	
00E	26H*	81B	96C		63Z*	34K	84T	67Z*	
00J		81C	96D	MUSIC		34Z	84Z	68G	
00U	AR	81Z	96H*	02B	QM			68H	
03C	19Z*	82B	96Z	02C	41J			68K*	
		82D	97B	02D	76P*			68M	
	AVN	83E	97C	02E	76Z*			71N	
	71P	83F	98Z*	02F	94B				
	93H			02G					
	93J			02H					

*No task list provided to date.

Table 6

Examples of Cluster Representative Tasks

Alpha

"Carry 45 kg CWIE bag 1000 m in 20 minutes."

Bravo

"Lift and carry 41 kg ammo box 6.7 m 32 times per hour."

Charlie

"Lift 132 cm and carry 25 kg projectile 15 m, 50 times per hour."

Delta

"Lift and carry 27 kg container 15 m, 40 times per hour."

Echo (complete list)

1. "8 km march in 120 minutes."
2. "Dig one-man emplacement in 45 min."
3. "Lift and carry 23 kg, 50 m, 8 times in 10 min."
4. "Rush 75 m in 25 sec."
5. "Low and high crawl 75 m in 90 sec."

The conversion of these physical and physiological units into field test event scores or AFEES measurement scores was then carried out by regression analyses as described earlier. An example is presented in Table 8 of the conversion of a task demand into a capacity and then into a field test standard. The purpose of this report is to present the process used to derive these standards and therefore the actual computed standards are not presented but will be published elsewhere.

VI. Discussion

This paper outlines the rationale and step-by-step process that can be taken to develop gender-free physical fitness standards for the Army based solely on occupational (MOS) physical demands. It establishes an objective basis for minimum physical standards for MOSs so that individuals can be selected and assigned to MOSs based on the physical demands of the MOS.

Table 7

Energy Cost of Task No. 14, Bravo Cluster: (lift and carry 45 kg Projectile 20 m, 100 Times Per Day).

Subject No.	B. Wt.	Energy Cost KCal/min
4654	74.9	1.00
4647	80.0	0.86
4648	81.5	0.88
4651	78.7	1.06
4334	70.0	0.76
4347	74.9	0.95
4397	77.8	0.93
4367	70.1	0.82
4337	64.9	0.72
4353	74.2	0.88
Mean	74.7	0.89
SE	1.6	0.03

Table 8

Example of Task Demand Conversion into Capacity and Field Test Standard (for illustration only, values may not be accurate).

1. Highest demand for cluster per 8 hour period = 8 kilocalories/min or 23 ml/kg/min $\dot{V}O_2$.
2. Capacity required if 23 ml/kg/min $\dot{V}O_2$ is to represent no greater than 45% of capacity = 51 ml/kg/min $\dot{V}O_2$.
3. Capacity of 51 ml/kg/min $\dot{V}O_2$ equivalent to 14 minute two mile run time.

It is recognized that a number of assumptions must be made during this process, some of them based on imprecise data. However, it is felt that the precision achieved is appropriate to the resolution desired.

Occupationally based fitness standards are not meant to be either the ultimate or sole physical fitness standards. They are intended to serve as a requirement upon which to base MOS assignment qualification at the time of enlistment into the Army and secondly, as the minimal standard that must be met to retain qualification in a particular MOS or for retention in the service. It is envisioned that, particularly in some operational units, these MOS-based standards could be exceeded in order to achieve the additional goals of improved health, appearance, morale and overall military performance. These additional or supplemental standards above the MOS requirement would be determined by unit commanders based upon the needs of their personnel and their unit mission.

In conclusion, this research has resulted in a process by which physical fitness demands of all enlisted MOSs can be represented by 5 sets of standards, representing three levels of demand in two separate categories of fitness. This categorization was accomplished by applying objective criteria to MOS tasks, including the weight lifted and rates of energy expended. This system establishes a basis by which physically demanding occupations can be assigned on a gender-free basis which will be both legally and scientifically defensible. It should lead to more cost effective matching of individual capabilities to occupational demands and thereby conserve manpower.

VII. References

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